THURSDAY, SEPTEMBER 18, 1913.

THE STRUCTURE OF THE ATMOSPHERE IN CLEAR WEATHER.

The Structure of the Atmosphere in Clear Weather: a Study of Soundings with Pilot Balloons. By C. J. P. Cave, M.A. Pp. xii + 144. (Cambridge: The University Press, 1912.) Price 10*s.* 6*d.* net.

MR. CAVE'S book is a welcome addition to the valuable contributions of amateurs to the common stock of scientific knowledge, and is the more welcome as the first book on this special subject. The investigation of the upper air is of such interest and the incidental problems which it presents are so numerous, so attractive, and, in these days of flying, so practical, that it is a matter of some surprise that there are not found more men of leisure to follow the notable examples of Prof. Lawrence Rotch and M. Teisserenc de Bort in the investigation of the free atmosphere. Mr. Cave in his introduction refers to the circumstances in which he began the study of the subject. As a matter of history, they can be traced to a letter by the present writer in *The Times* asking for the cooperation of yachtsmen in the exploration of the air over the sea by means of kites. Since that letter appeared we have had to chronicle the division of the atmosphere into two distinct layers, an upper layer, the *stratosphere,* in which there is little or no variation of temperature in the vertical, but sensible variation from day to day, or along the horizontal, and a lower layer, the *troposphere,* in which the variation of temperature is greatest in the vertical and relatively small along the horizontal. At the boundary between the two layers which is found at different heights in different regions, and on different occasions according to the barometric pressure, there is generally a slight inversion in the fall of temperature with height. Ten kilometres may be taken as a rough and ready estimate of the average thickness of the troposphere with the understanding that there is a latitude of three or more kilometres to be allowed in either direction according to circumstances.

With the progress of the general investigation of the upper air attention has been directed especially to the observation of air-currents at different levels by means of pilot balloons watched through theodolite-telescopes of special construction, introduced by M. de Quervain. Mr. Cave's book gives a comprehensive account of the methods and results of work of this character based upon his own experience at Ditcham Park and elsewhere. The apparatus is simple and less expensive than that required for the determination of temperatures:—a balloon which need not be large enough to carry recording instruments, some hydrogen, and accessories, two theodolites to be used simultaneously from two ends of a base for the observation of the altitude and azimuth of the rising balloon at the end of each minute or half minute from the start. One of the theodolites may be dispensed with if the observer knows with reasonable accuracy the rate of ascent of the balloon, and, as appears from one of Mr. Cave's chapters, this condition may be assumed without fear of losing the characteristic features of the ascent. In fact, observations of pilot balloons with one theodolite have been asked for as part of an international enterprise. The reduction of the observations is laborious, as each sounding entails the solution of many triangles, but with the judicious use of a slide rule and tables as described on p. 12, the labour is apparently not intolerable. The results of two hundred soundings in 1907, 1908, and 1909, with one in 1910 involving the solution of 8000 triangles, are given in the book. They are classified according to certain types of structure. For each sounding the velocity and direction of the horizontal motion of the air at each half kilometre are given in tables on pp. 84–107, and they are illustrated by a number of diagrams showing the variation of direction and velocity with height, accompanied by the weather maps which represent the distribution of surface pressure on the occasions of the ascents. A word of praise must here be given for the excellence of the arrangement and printing of the tables and of the diagrams and maps.

The order of the book also deserves remark. Mr. Cave has departed from the usual course in not taking the mean values of all the fish that have come into his net. He has sorted out his catch before submitting it to digestion. In fact, there are, if we recollect rightly, no mean values anywhere in the book. In the present state of our knowledge this decision is a wise one, for until the variations are reduced to those of observation alone, a mean value often conceals more truth than it reveals, and is sometimes actually misleading.

The first step in the discussion is to form a selection of types of structure. These are excellently illustrated by photographs of cardboard models.

The use of pilot balloons is subject to some obvious limitations. There is no little difficulty in pursuing a balloon with a theodolite for great distances. On one favourable occasion Mr. Cave kept a balloon in view until it was forty miles away, but ordinarily a sounding comes to an end by losing sight of the small speck in the field of

D

view of the theodolite either by a trick of eyesight or by the accident of clouds, long before any such distance has been reached. Consequently, the investigation is limited to clear weather, and for the most part to the lower layers of the atmosphere. The lower half of the troposphere, say, up to five kilometres from the surface, is the region specially under observation, but when the sky happens to be clear the investigation can be extended to much greater heights. Mr. Cave gives twelve examples of series of observations beyond 11 kilometres, and one up to 18 kilometres. He is therefore able to devote a chapter to the winds of the upper layer, the stratosphere, and he supports the general conclusion that the wind falls off rapidly as the boundary of the stratosphere is approached and passed, though we must wait to learn whether this result is characteristic of the stratosphere or merely characteristic of the weather when the stratosphere comes under observation.[1]

Useful chapters will be found devoted to methods of observing and their accuracy, and to the rate of ascent of balloons, with an examination of the effect thereupon of the orographical features of the neighbourhood. The author then takes up the meteorological applications of his results. This section takes the form, for the most part, of a study of the relation of the strength and direction of currents aloft to the distribution of pressure and temperature at the surface, and leads up to an important diagram on p. 75 showing the upper winds in relation to a hypothetical distribution of high and low pressure at the surface. The diagram represents increased velocity aloft in the westerly currents of a "low," and in the south-westerly and north-westerly currents of a "high," but a diminished velocity in the easterly wind of a "high." To judge by the text, an unchanging current might have been represented in the more central area where there is little pressure gradient, and certainly a reversal of the north-easterly current on the south-eastern side of a high-pressure area. But the most striking feature of the diagram is a strong north-westerly upper current increasing with height (across the surface isobars and the south-westerly surface winds) from the central region of a "low" to the eastern region of the neighbouring "high." This noteworthy current which must be closely associated with the dynamical structure of the atmosphere is rightly selected as one of the types of structure to which attention is specially called. It is in line with observations of cirrus cloud in front of a low-pressure area.

The relations to the sequence of weather on many occasions are set out in detail, but the results are not easily generalised except in the special case of the reversal of the current over a north-easterly wind, which is shown in many instances to be the precursor of rain and thunderstorms.

Some attention is given to the relation of the direction and strength of the wind in the upper air to the pressure gradient at the surface, assuming that the gradient wind is tangential to the isobars. As regards direction, there are useful diagrams showing the relation of the gradient directions to the surface winds for the three types of structure, viz.: (1) "solid current," (2) increase of velocity aloft, and (3) decrease of velocity aloft; the last shows the decreasing winds to be limited to cases of surface wind between north and south-east. As regards strength, gradient velocities are calculated from the usual formula:

$$V = \gamma/(2\omega\rho \sin\lambda),$$

and the increase of velocity with height for some situations is attributed to an increase of gradient deduced from the distribution of temperatures in the lowest layers indicated in the published weather-charts.

The increase of gradient is calculated from the surface temperature by a rough and ready formula which, considering the local influences upon temperature and other circumstances, is sufficiently accurate for Mr. Cave's immediate purpose; but it may be useful to give here a more accurate formula, to which that used by Mr. Cave approximates. Neglecting the effect of humidity, which is certainly small and usually unknown, the *increase* of pressure difference in millibars for h metres of height measured from any level is given by the formula:

$$\Delta p_h - \Delta p = 0{\cdot}0342 h \frac{p}{\theta}\left(\frac{\Delta\theta}{\theta} - \frac{\Delta p}{p}\right),$$

where p is the pressure at one place, $p + \Delta p$ that at another on the same level, θ and $\Delta\theta$ are the temperature and temperature difference, and Δp_h is the pressure difference at h metres above the given level.

Near the surface p/θ is approximately equal to 3, so that for the first k kilometres from the surface the formula would become approximately:

$$\Delta p_k - \Delta p_s = 100k\left(\frac{\Delta\theta}{\theta} - \frac{\Delta p}{p}\right)$$

The approximate formula used by Mr. Cave is practically identical with this, except that the term $\Delta p/p$ is omitted. The omitted term may be sufficiently small to be neglected for the surface layers when Δp is not large, because p is numerically of the order of 1000 in that region, but $\Delta p/p$ cannot be neglected in calculations requiring greater accuracy, or in the upper reaches of the atmosphere, where p has a much smaller value because θ does not fall proportionally to the fractional fall of p.

---

[1] The falling off of wind with height in the stratosphere can be shown to be a logical consequence of the higher temperature of the region of lower pressure.

In considering any physical explanation of the structure of the atmosphere, the difference $\Delta p/p - \Delta\theta/\theta$ is an important quantity. In fact, as a rule, it appears that, somewhere or other in a vertical section of the troposphere (where $\Delta\theta$ and Δp are of the same sign), in consequence of the variations in the magnitudes involved, the quantity $\Delta p/p - \Delta\theta/\theta$ *becomes zero and changes sign.* To that curious circumstance is due the dominance of the influence of the stratosphere upon the dynamics of the surface layers, although it only represents about a quarter of the whole mass of the atmosphere. In the stratosphere Δp and $\Delta\theta$ are of opposite signs, and their influences in the production of pressure difference reinforce each other. Hence in the stratosphere, pressure differences are rapidly built up, while in the troposphere changes are capricious and contradictory.

But fortunately these considerations are, so far as can be judged, of little importance in the cases to which Mr. Cave has applied his rough and ready formula, and do not affect the general accuracy of his conclusions.

For the practical study of the dynamics of the atmosphere we are largely dependent upon observations with pilot balloons. They may be taken as supplementing observations of clouds, and, in due time, both must be brought into relation with the observations of pressure and temperature obtained from registering balloons. It is in many ways unfortunate that the track of a registering balloon cannot always be followed by a theodolite or otherwise determined. As it is, we often get our kinematical conditions from one occasion, and our baric and thermic conditions from a different one.

Something may be done to bring the two together by means of observations of cloud-sequence, which can be observed on either occasion. At present these have hardly come within the range of meteorological work. Few observers are effectively conscious of the rapidity of the changes which are indicated by clouds, and which must be the results of the distribution of pressure, temperature, and wind.

In the book before us little is said of the association of cloud-forms and cloud-changes with the variations of the structure of the atmosphere disclosed by pilot balloons, but that part of the subject has great possibilities, and this leads us to express the hope that in a subsequent edition of this interesting work Mr. Cave may be able to give us the benefit of his experience in that direction also.

W. N. SHAW.

SOCIOLOGY AND MEDICINE.

(1) *The Task of Social Hygiene.* By Havelock Ellis. Pp. xv+414. (London: Constable and Co., Ltd. 1912.) Price 8*s.* 6*d.* net.

(2) *The People's Medical Guide: Points for the Patient, Notes for the Nurse, Matter for the Medical Adviser, Succour for the Sufferer, Precepts for the Public.* By Dr. John Grimshaw. Pp. xx+839. (London: J. & A. Churchill. 1912.) Price 8*s.* 6*d.* net.

(1) THE title of this book somewhat masks the nature of its contents, for by "social hygiene" the author means to convey the study of those things which concern the welfare of human beings living in societies. The various chapters, or essays as they practically are, include such varied subjects as the changing status of woman and the woman's movement, eugenics and love, religion and the child, the falling birth-rate, sexual hygiene, war against war, international language, and others. The author generally presents the two points of view, supporting them by quotations and summaries from many sources. The essays are interesting reading, but at the end leave us somewhat in doubt as to what would be for the best, or what the writer considers would be best.

(2) This book covers almost the whole range of subjects comprised within the scope of the practice of medicine and surgery, including the specialities such as diseases of the throat and eye. The information given seems generally to be accurate, is imparted in simple language, and important points are frequently driven home by some terse sentence, *e.g.* "a tooth in the head is worth two on the plate" (p. 57). Some capital sections are given on the management of children, diets and cooking, and physical exercises. The matter does not always seem to come quite in the right place, and simple domestic remedies and treatment may be omitted; for example, that common complaint of children, "child crowing," or "spasmodic croup," is scarcely noticed under children's ailments, but is relegated to the chapter on diseases of the throat, and it is certainly by no means "invariably" associated with rickets.

We think that the compass of the work is somewhat beyond that necessary or desirable for the general public, but the volume would serve as an excellent book of reference for the district nurse, health visitor, missionary, ship's captain, and the like.

R. T. H.